Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating:

Review:

What is the intellectual merit of the proposed activity?

I have addressed these issues in the summary statement. My remarks do not cover proposed studies in geoscience, biology, materials and tracer techniques.

What are the broader impacts of the proposed activity?

I have addressed some of these issues in the sumary statement.

Summary Statement

This purpose of this proposal is to provide the infrastructure for a major UG laboratory, and an initial set of laboratories for smaller experiments. Costs of major additional experiments are not included-such laboratories and some of the smaller laboratories "will be built to order".

**General Comments

The Bahcall Report provides a useful description of the important physics that could be done at an underground laboratory. However, neither that report, nor the present proposal, presents a detailed study of what is gained by going to depth. I.e., what is the cost benefit ratio? In that circumstance it is difficult to know what to make of the statements that depths greater than 4000 mwe are needed for most of the experiments listed in Table 1, p C-4.

As a result, it is extremely difficult to judge this proposal. It is not clear what level of expenditure is justified by the science. There is no question that good science will be done, but a convincing case has not yet been made that it is the best science that could be done with equivalent funds. And it is far from clear that the exact develpment proposed for Homestake is the best approach.

**More specific concerns and questions:

What is the projected long term operating budget? Is the roughly $20 M for the fifth

year the asymptotic budget?

The contingencies may be insufficient. While a reasonable first estimate based on reasonable assumptions has been presented, at this stage of design, a larger contingency, perhaps-40%, would seem reasonable. As noted a number places in the Notes to the Tables, significant uncertainties remain in the design, although mostly in the upper campus. There was apparently an emergency evaluation of Homestake during the 1993 flood (see LOI-15); it is not clear what is necessary to deal with this possibility. A 25% contingency is what I would assume for a project in which a conceptual design report had been funded and carried out to examine the costs and scope in more detail than has been possible on the present time scale.

Will some of the research proposed have to be classified (weapons monitoring)? If so, is this appropriate in an NSF multi-user laboratory?

A made to order laboratory may be appropriate for a first generation experiment, but not for the experiment that will follow it on the floor. Is a more useful procedure for the long run to provide general-purpose space that is adapted to a particular experiment as part of the cost of that experiment?

Is the absence of high ranked educational institutions in the Homestake area to be regarded as a negative (as it probably is for scientific productivity), or as an opportunity for improving these institutions?

Summary comments:

From a scientific and technical point of view, funding of an UG laboratory at Homestake is not yet ready for decision. There should be a much more open discussion of the science that will be achieved for the investment that is projected. This should be in a broader context than is possible by this Panel. Many of the larger projects will probably be funded mainly by particle physics; before a funding decision is reached, NSF needs to know whether expenditure of funds at the projected levels is a sufficiently high priority of the particle physics long-range plans. Or whether the NSF is prepared to bear the long term operating and expansion costs of the laboratory (following completion of the project outlined in this document) given the value of the science.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating:

Review:

What is the intellectual merit of the proposed activity?

The case for a National Underground Science Laboratory is a very strong one. Underground science is rapidly becoming one of the most important and productive areas of study in particle physics and astrophysics. The existence of a major international laboratory capable of supporting these types of experiments in the US will have a significant positive impact. This proposal leans heavily on the work of two committees which have studied the question of underground science and of the site for a proposed laboratory. I will only say that I believe that these panels did an excellent job and their reports support this proposal. There is a case to be made for looking at other sites (as was mentioned in the site report), but that is something that I will not comment on further.

As to this specific proposal, I withhold final judgment until the completion of the panel review, but I have a number of comments to make preceding that review.

" As I pointed out earlier, the case for underground science, in general, is strong. However, I would not recommend full funding of a laboratory of this size without have at least one and preferably two major flagship experiments that would be done at the laboratory. This will put the actual science into the proposal to get it rolling.
" This brings up the issue of the total cost of doing an experiment at the site. The proposal needs to be evaluated in terms of what it, plus the experiments that will likely drive the lab, will cost together.
" Given these concerns, I believe the scale of the proposal to build a laboratory is reasonable. It is certainly possible to do an experiment with less infrastructure than this, but if you are going to build a facility that will encourage new and innovative proposed experiments, this is the right scale.
" I am not comfortable with the proposed management scheme, laboratory organization and oversight. One rarely builds a national/international laboratory as the result of a single NSF proposal, so I understand how this problem arises. However, I see real issues here. I have no problem, with the specific members of this proposal, being on the oversight board. (As a matter of fact they would be excellent choices). What I don't see is why their institutions should be permanently represented on the board.
" I have a similar objection for the research universities from the region. I see no

reason that they should have such a large voice in scientific decision making. I do see an important (and permanent) role for them in education and outreach, but not in making critical decisions about questions they may have no expertise in.
" I believe a more straight line management structure is needed. The lab will have to work closely with multiple funding agencies and will have to be directly responsible to NSF and I am not sure this proposal will produce that.
" Unlike a simple user facility, major experiments will require significant funding to the laboratory as well as to the PI's building the experiment. I feel strongly that the issue of how the funding of both the lab and experiments work together needs to be clearly worked out by both the proposers and the funding agency. The lab cannot be expected to submit an "unsolicited proposal" to NSF to pay for its share of construction of a cavity.
" The outreach proposed here is outstanding. The authors should be commended for taking it seriously.
" Operations of a mine like this will take serious resources. The proposal requests about $5M annually to do this, but there is no way for me to tell if this is reasonable.
" I am concerned that a mining operation is a serious matter. In this proposal, we do have seem to have serious expertise in mining involved. While I realize that the mining company will be involved, it looks like they are doing what they can to distance themselves from this project. This needs to be addressed.

I have a series of other minor concerns that I will address with the panel.

What are the broader impacts of the proposed activity?

Summary Statement

My bottom line conclusion is that at this stage I believe the idea of a National Underground Science laboratory is an excellent one. I believe that the possibility of using Homestake must be preserved until all the questions are answered. I understand that funding has just been secured to support this. This is good because "A mine is a terrible thing to waste"!

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

see below, following the instructions for the panel

What are the broader impacts of the proposed activity?

see below, following the instructions for the panel

Summary Statement

Comments covering:

-- scientific justification:

Neutrino astronomy was born in the Homestake mine with the first observation of neutrinos emitted by the sun. Their measured rate disagreed however with conventional calculations describing the nuclear processes by which the sun burns. A few days ago the SNO experiment in a deep mine in Canada showed that the solar neutrino beam 'oscillates,' proving that neutrinos have mass. The discovery represents a dramatic 'proof of concept' of particle astrophysics: a fundamental discovery in particle physics emerged from astronomical data. The rapid rise of particle astrophysics as a discipline at the boundaries of astrophysics, cosmology and particle physics made this success possible. We have recently witnessed an explosion of new experimental techniques leading to more sophisticated and more sensitive experiments in particle astrophysics. Among them, the experiments that involve neutrinos must be deployed underground to be adequately shielded from the cosmic radiation at the surface of the earth; recent second-generation experiments such as SNO require increased depths. Because SNO's depth is not accessible at the only existing underground laboratory, the Gran Sasso National Laboratory in Italy, the collaboration, like many other around the world, had to create its own infrastructure, in this case in a deep nickel mine in Sudbury, Ontario. Homestake can accommodate experiments at more than twice the depth of Gran Sasso, depths adequate to accommodate a detector like SNO. The end of mining at Homestake presents the scientific community with a timely and totally compelling opportunity to create an underground laboratory in the US.

-- timeliness:

With the rapidly increasing interest of the astrophysics and particle physics communities in neutrino experiments, the time has come to provide the US scientific community with an alternative to Gran Sasso. The convenience of a nearby infrastructure that can support future experiments will undoubtedly invigorate this exciting field. Actually, for certain background-limited experiments it is a requirement because exposure to radioactivity during transportation to Gran Sasso makes deployment from this side of the Atlantic impossible.

The proposal is a FY03 MRE. The inevitable timing of the transition of Homestake from an operating mine to a laboratory requires that funding be found before FY03. Effective exploitation of the laboratory will also require significant funding for experiments beyond the funds requested in the proposal, not only from the NSF but, realistically, from other funding agencies. It is difficult to review this proposal in the absence of an integrated funding plan for the experiments that the laboratory will accommodate.

-- underground science:

See above. Also, the manpower of the laboratory's scientific personnel seems reasonable, adequate to form a critical intellectual presence at the laboratory. This is essential for attracting qualified scientific personnel before local institutions can evolve into a center of excellence in underground science.

-- laboratory construction:

The initial layout seems reasonable. The actual structure of the laboratory should evolve with the approved experiments. Insufficient detail is provided on large key budget items in the proposal.

-- laboratory management:

Only top-level management is presented. As I understand it, there are separate management structures for operation and funding and administration. At this stage of the project the management seems sound.

The Gran Sasso laboratory in Italy has evolved into an international facility in a scientific discipline where international collaboration has been the rule. While the proposal states that Homestake should be international, I cannot identify aspects of the laboratory plans and management which facilitate this.

-- outreach and education:

The education and public outreach plan is impressive. It should be given the unique opportunities presented by a laboratory that combines a historic mine with the public fascination with neutrinos and the Cosmos. Some comments however: It is generally agreed that the most efficient way to promote science with students of all ages is to expose them to working scientists and their experiments. Here the plan seems to fall short, despite the weekly talk by faculty mentioned in the proposal. I feel that a bigger effort should be made to expose the scientists employed by, or doing experiments at, the laboratory directly to local students at all levels. They deserve better than a tour shared with tourists. Conversely, students should be given the opportunity to get directly involved with experiments in the laboratory, especially the students in the REU program. Finally, there is no evaluation of the education and outreach program.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

See my summary.

What are the broader impacts of the proposed activity?

See my summary.

Summary Statement

This is a review of NSF proposal 0127107 : " Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake". This review is being written prior to the Review Panel meeting to be held 29-30 June.
The proposal is for $281M over 5 years to create a new laboratory for a wide range of science in the site of the Homestake gold mine in South Dakota.
The PI is W. Haxton (U. of Washington) with four Co-PI's (J. Conrad, Columbia U.; S. Farwell, So. Dakota Mines: M. Marshak, U. Minnesota; J. Wilkerson, U. Washington). As a group these are all persons of appropriate competence and expertise.

While this proposal does not constitute a full technical design, it is detailed enough and the scope made sufficiently clear that I feel an adequate judgment can be made on its worthiness to be carried to the next level or not. The proposal itself follows the usual NSF limitation (30 pages) on the main text but is supplemented with some valuable Appendices. I found both the main text and the appendices to be well written and cogently presented.

Turning to the specific elements of the charge to the review panel:
1) Scientific justification. I am most familiar with the areas of neutrino physics (atmospheric, solar, supernovae, long base-line), double beta decay, dark matter, proton decay and the detectors for all. In each of these areas there is very strong scientific justification. The questions to be addressed by future experiments (which would be done in such a lab) are some of the most central in particle, nuclear and astrophysics. The recent discoveries in the apparently diverse realms of neutrino physics and supernovae red-shifts emphasize both the unity of much of the physics and the need for extensive new experimentation. There is presently intense activity in

these communities preparing and/or considering how best to carryout such experiments. These range from "traditional" underground experimentation such as solar neutrinos to advanced accelerator concepts using long-baseline detection. In all cases, the experiments need to be underground for purposes of achieving sufficiently good signal to background control but not all have exactly the same requirements; however, Homestake appears likely to be able to provide
the necessary environment for all of the topics discussed above. Reduction of backgrounds leads to increased sensitivity which is essential for progress. I found the Table 1 in the main text, and the discussion in Appendix A, to be an accurate and concise outline of the motivation for these areas of physics.

2) Timeliness. It appears to me that there are two aspects to the 'timeliness' element. The first has to do with the timeliness of the physics to be done and the other is the window-of-opportunity presented by the closing of the Homestake mine.
On the physics side, I would mention four things indicating the timeliness for a US National underground lab: a) the present results and discoveries particularly in neutrinos (solar, atmospheric, supernova) and in dark matter/energy argue for new more sensitive experiments in these topics, b) those results and new developments in detector technology argue that new sensitivity in double beta decay and proton decay can and should be achieved, c) a realization that the overburdens at the present leading underground labs (Kamioka and Gran Sasso) need to be exceeded for many such experiments (a new lab would provide this) and d) even those experiments not requiring increased overburden are compromised by long-term congestion at Kamioka and Gran Sasso. US scientists are in the forefront of thinking and preparing for these new generations of experiments; if the US is to take the leadership in these fields of underground science it is not too late to create a US site for them. The gestation of the likely experiments and the long-term development of the type of lab proposed here seem a good match to me.
These are issues which have been with us for some time. We might wish for a better timescale than is presented from the action by the owners to close the mine. However, I believe the proposers have made a strong case that, considering the other options , Homestake should be regarded as the most likely to achieve the quality of lab required for the science in a timely way.

3) Major Components: [underground science, laboratory construction (lower/upper campus, access, systems), management, outreach/education, program planning]

I have mentioned above my opinion that the significance of the science in my areas of experience is outstanding. The science to be done has clearly driven the basic design of the laboratory and its evolution. This is reflected in the designation of the upper (but still underground) and lower campuses where experiments have been grouped according to as many common needs as possible for both necessary environmental conditions and likely systems requirements.

I received the impression that serious attempts have been made to make the lab high

quality from the science-to-be-done-there point of view without being at all lavish. Quite reasonably they try to make as much use as possible of existing adits, drifts and spaces while seeking ways to close off the rest. This appears to be most evident in the underground portion of the upper campus where generally smaller and/or less demanding experiments can be located. Some of these same experiments might also be the first to be ready and that might fit well in the longer term development of the lab.
I think most everyone would agree that the ideal underground lab would have horizontal access for major equipment and that the locale would not be shared as dual purpose. This proposal, in its plan to augment the Yates shaft and lift capability, is a sound and cost effective remedy to the former; the cessation of mining obviates the latter.
The design concept for the lower campus is attractive from the point of view of the type of experimentation to be done there. It reflects the thinking and conclusions of the Technical Evaluation Group (see Appendices at end of 'Bahcall' group report) which I consider to have done a surprisingly good and even-handed job in limited time. Some excellent and experienced persons constituted the Technical Evaluation Group. The "straw-men" experiments they used as examples of scale and systems needs were perfectly appropriate and likely representative of what might actually materialize.

I interpret the terms 'access' and 'systems' used in the charge to us in a way perhaps not intended. The take I can give to them is from the point of view of a working experimentalist who assumes that all the issues implied for health, safety and labor practices will already be taken care of in their statements to adhere to all the relevant laws and practice. Some real pluses I found were their exposition of the needs of the experimenters for 24-7-52 access to the hardware and other details such as EM isolation in power, high speed communication channels, underground storage place for 'cooling' of cosmogenic activity in materials to be used in detectors --- it shows an awareness of the real purpose of the lab without frills. I found especially attractive the recognition and provision for a world-class low activity facility to assay activities in detector materials; a facility with capability at the several ppb-level or better would be a valuable national service to a number of fields. It must be done deep underground.

There is not a great deal of discussion in the proposal as to what will be above ground. That is probably appropriate at this juncture until a detailed knowledge of what existing buildings and in what condition they are becomes available. They do however discuss the need for a limited set of shop, staging and library facilities and make some estimates of the cost. Additional discussion of what outreach/education structures are needed is given.

Lab management and the program of experiments are intimately connected in my mind. Without good lab management there can be no lasting first-class science program. What they have proposed seems to be a cross between the NSF Science Board and the management of an accelerator program in a national lab. I've had

plenty of experience with the latter but none with the former. I understand the need for the representation of the various constituencies and this is perhaps the best way to start; however, I suspect it will evolve to a somewhat different form. My concern is for well-being in the performance of the science program. I am not a management expert but I like the model where the PAC (Program Advisory Committee) is entirely composed of active scientists with the Lab Director as Chair. As far as the PAC's work on the program is concerned, the buck stops at the Lab Director. And the Lab Director is responsible to the trustees and agencies. There is of course the complicated dance among experimenters, agencies, lab directors and ad-hoc committees about the funding of individual experiments but somehow it all has seemed to work quite well up to now. Perhaps I missed the true role of the USNUSL Science Board but what I understood of it, it seems a bit clumsy for the day-to-day science program and may get bogged down.

The need for an interim management and financial plan prior to the full approval of Homestake was argued for. As I understand it, its principal purpose is to keep the local skilled and experienced people available and involved in the technical design of a full lab proposal and, hopefully, its full realization as a functioning science center. This seems an important thing to do and might well influence favorably that crucial stage of development.

I especially liked the outreach. Much of it builds, and acknowledges, the work and success of others before them but in contrast to others (except perhaps for Soudan) it strikes me as an approach to a fresh community of some size and significance. Many of us are more familiar with the existing urban community outreach programs. This one, with its emphasis on Native Americans, seems tailor made. There is an infrastructure of various types of educational and organizational institutions already based in that community and geographically well situated. The sketch of the mechanics as to how these interactions with the community might work seems quite reasonable.

4) Conclusion.
Overall, my opinion of this proposal is strongly favorable. It is aimed to fill an important need in US science and reflects judicious consideration of alternative ways of trying to fill this need. I feel it should be given favorable action and encouragement now to insure that this unique opportunity not be lost from further consideration. I give it an excellent score.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating:

Review:

What is the intellectual merit of the proposed activity?

The reasons behind an underground science laboratory are compelling. The scientific potential of an underground laboratory are immense. These are summarized in Table 1 of the Project Summary. It is obvious that a major underground lab will play a leading role in future experiments and will have a significant impact upon several brances of physics, such as nuclear physics, nuclear astrophysics, particle physics, etc.

What are the broader impacts of the proposed activity?

The educational impact of the proposal are tremendous, both in terms of research training for undergraduate and graduate students, as well as education of k-12 students and the general public.
The potential of involving local students in the area is exciting.

Summary Statement

The justifications for an underground lab are excellent. An underground science laboratory has immense scientific potential.

The proposal recommends strongly that the site of the underground lab be the Homestake mine. The Homestake mind is scheduled to close in the very near future. Therefore, the proposal stresses the need to act immediately.

However, the proposal does not talk about any specific scientific experiments to be performed -- the proposal gives several examples of possible experiments, and includes letters of intent, but does not actually propose any specific projects to be performed in the lab.
There is also no detailed scientific justification given in the proposal.

A final evaluation of the proposal is reserved until after the panel review.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating: Very Good

Review:

What is the intellectual merit of the proposed activity?

The proponents make a strong case for a National Underground Science Laboratory (NUSL) that would host a diverse range of scientific experiments, across several disciplines. I agree with the authors' contention that such a laboratory could yield results that would have far-reaching consequences for science. I believe that the work of the proposed laboratory would be of great intellectual merit.

The proposal of NUSL is timely. During the time period during which NUSL will be established and its first experiments deployed, we anticipate great strides in understanding the neutrino deficit problem from the work of the Sudbury Neutrino Observatory (SNO). The work of NUSL will complement and extend that of SNO just when the latter will be reaching its systematics limit.

The establishment of a world-class underground laboratory, housing several complex experiments, is a major undertaking replete with difficult problems that will have to be solved, such as reducing the dust and radon levels to that required for sub-MeV neutrino physics at a reasonable cost. One does not really know, at this stage, how costly this will be. Flexibility on the part of the NSF will be necessary if NUSL is to succeed.

Whatever the proposed management structure, it is crucial (from the outset) that the laboratory director be granted a high degree of autonomy to run NUSL as he or she sees fit so that the laboratory can respond flexibly to changes in scientific interest.

What are the broader impacts of the proposed activity?

The discovery of weakly interacting massive particles at NUSL may help solve the mystery of dark matter. This would have a direct impact on our understanding of the evolution of the universe, which depends on its total mass-energy density, as well as our understanding of physics at extreme energies. An accurate measurement of the solar neutrino energy spectrum would provide detailed information not only about the nature of neutrinos but also about the nature of the Sun. A better understanding of the Sun would improve our understanding of stars and their evolution.

The authors did not comment specifically on what they see as the long-term future of NUSL. But one could envisage, after the resolution of the dark matter and neutrino problems, the flowering of a new astronomy based on the detection and analysis of weakly interacting particles from space.

It is made clear in the proposal that outreach is not an afterthought, but something that is fully integrated into NUSL's mission. The authors should be commended for their conscious effort not to ignore Native Americans. As the authors make clear, NUSL provides a rare opportunity to include, "somehow", this oft-forgotten peoples. Of course, much work needs to be done to define what is meant by "somehow" and what are the goals.

Summary Statement

This proposal is about enabling science of the highest intellectual merit that not only pushes at the frontier of physics, astrophysics and cosmology, but also excites the imagination of scientists and lay-persons alike. I strongly support the establishment of a national laboratory. But one should recognize that its precise form is far from determined and requires considerable more discussion with the larger physics community.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating: Excellent

Review:

What is the intellectual merit of the proposed activity?

The intellectual merit of the proposed activity is very high. It promises to address some of the most important questions in science. It is also likely that definitive answers can be obtained to some of these questions by way of this proposed activity.

What are the broader impacts of the proposed activity?

The proposed activity will bring together several different areas of science, so in that aspect it already excells on this criterion. However, the proposers are also paying special attention to the opportunity to have important impacts educationally and on society at large. In particular, the opportunity to have an important impact on Native American students is very attractive.

Summary Statement

This is a rather unique proposal and opportunity. In a real sense, it is premature and missing answers to some important questions which must be answered before we really know if the project can succeed. However, there is also an extremely important scientific opportunity described in the proposal, and there are strong practical reasons to assess now whether the Foundation should begin a process which might well lead to the establishment of a National Underground Science Laboratory.

The scientific questions to be addressed by the proposal are broad and deep. The field of underground science, which usually means those experiments which require very low backgrounds from cosmic rays and associated radiation, involves important areas of nuclear physics, particle physics, and astrophysics. There are also interesting problems in materials science and biology which can benefit from this environment. The United States has had important efforts in this area for decades (e.g. the Davis experiment in Homestake and the Soudan experiment in Minnesota), but we do not have a real underground facility which can be used by a variety of scientists. The most versatile facility in the world at present is the Gran Sasso Laboratory in Italy, but it is oversubscribed and its depth is not sufficient for many of the next generation of important experiments. The closing of the Homestake mine presents us with an opportunity to establish a world-leading facility in this emerging

area. I accept that a signal is needed soon as to the desirability of pursuing this opportunity, and therefore I would strongly recommend that indeed a positive signal is given. Certainly enough resources should be made available, one way or another, to prevent action which would make it difficult if not impossible to use Homestake for this purpose. However, there are important questions which need to be addressed before a full commitment to proceed is made. Below I list some of these questions and issues. They are given in the spirit of trying to make the ultimate facility as valuable and as capable of doing excellent science as possible.

1. The arguments presented by the proposers for concentrating resources on one major facility, and for making Homestake that facility, are compelling. However, it will be important to make sure that all interested parties have had a chance to consider these critical questions.

2. Obviously, very little detailed information on the experiments which will eventually be sited at the lab was given. This is understandable given the short time frame, however, the scientists must now move as quickly as possible to present real collaborations with real detector proposals which can be evaluated in the usual ways. In particular it is important that all costs for the facility and experiments be considered in making the final decisions on proceeding and on a funding profile.

3. The education and outreach plans outlined were most impressive. However, experience shows that the best intentions can often still come up short on results. The proposers should look at some examples of good results elsewhere in detailed design of this aspect. Such examples might include those at JLab and at Soudan.

4. The management plan presented clearly needs more work. It will be important to have the right combination of scientific direction, construction and operation management, and accountability to funding agencies and oversight boards. This is a huge project: is physical size, in cost, and in complexity. The impression of this reviewer is that the complexity is probably underestimated by the proposers.

5. Just as it is important that NSF take action to get things going soon, it is also important for the proposers to move quickly. Workshops and conferences are important to define the detailed scientific case (in particular to demonstrate which specific experiments will benefit most from the deeper environment) and to create real experimental proposals and detectors. It is also important to establish a real presence at the Homestake site. Experience shows that having such a presence is critical to issues of credibility and the speed with which the project moves.

In summary, I am strongly supportive of proceeding with this proposal. I believe there is an excellent chance of truly good science emerging in the coming years.

Title: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

Institution: University of Washington

NSF Program: Particle Astrophysics

Principal Investigator: Haxton, Wick C.

Rating: Very Good

Review:

What is the intellectual merit of the proposed activity?

There is a high degree of intellectual merit.

What are the broader impacts of the proposed activity?

Very broad impacts to society at large including education.

Summary Statement

“Underground Science for the 21st Century: The National Science Laboratory at Homestake”

The proposal provides a detailed description of a NUSL at the existing Homestake mine. A review of the proposal documentation yields a reasonably clear picture of the scope of the potential science program and the operations of the mine as a science laboratory. There is a strong argument provided for immediate consideration of the Homestake mine as the site of a national underground science laboratory given the current plan for mine closure.

While the proposal appears to be generally strong there are elements of the proposal that are not adequately addressed given the significance of an award decision. A decision to establish a national underground science laboratory at Homestake is a commitment to support the life cycle cost (~$1 billion) and the redirection of a major fraction of existing underground science research to the NUSL science program. Areas of the proposal that need to be strengthened include: 1) the distinct management approach required for “transition” and initial construction vs. steady state operations of the NUSL; 2) a list or description of roles and responsibilities for each organization and individual from NSF down to the associate laboratory directors including stakeholders and external advisory committees; and, 3) project management plans including the acquisition strategy, plans for establishing MOUs between participants including legal contracts, and the expected flow of funds to the organizations completing work.

The proposal describes a management model that is very similar to the arrangements

used at other national laboratories. This model calls for the selection of a laboratory director with a proven record in underground science and project management skills. The science board of a not-for-profit consortium appoints the director. The consortium establishes a visiting committee that evaluates the science program, the laboratory director appoints a program advisory committee that advises on the laboratory’s scientific program, and a user’s committee represents the interests of the scientific community participating the laboratory’s research program. The application of the model for laboratory management to the situation at Homestake and the NUSL raise a number of concerns.

The composition of the proposed Consortium for Underground Science (CUS) includes the NSF. It is undesirable and probably even unacceptable for the NSF to be a part of this organization. NSF has a distinct role as the funding organization. Once the NSF is removed from the CUS the consortium becomes very similar to Universities Research Associates and Associated Universities Incorporated, the original operating contractors for Fermilab and Brookhaven National Laboratory. These organizations were established to assure that the unique character of academic operations is applied to the national laboratory operations. Experience indicates that the industrial aspects of laboratory operations are quite demanding. This is certainly the case for Homestake and the NSF prime contractor (CUS) must have adequate capabilities to address the laboratory operations issues. This can be achieved in different ways, e.g., through membership in the consortium or as through contractual relationship to the consortium. In any case the proposal must address these two roles: management of the scientific program and managing laboratory operations. In addition there are unique challenges that must be addressed in establishing a new laboratory and the proposal should address how CUS will be able to meet these.

Clear lines of authority and accountability are extremely important and should be explicitly addressed in the proposal. The unique and important role of the South Dakota must be addressed in some detail. These responsibilities extend beyond owning the land. Questions regarding liability should be addressed.

The proposal should provide more detail on the responsibilities of the Laboratory Director and the manner in which the director determines the science program. Is the Program Advisory Committee focused on NUSL or should they be expected to consider a more national or even international viewpoint?

There is very little detail on the organization structure of the laboratory. The roles and responsibilities of the ALD for Construction and the ALD for Operations should be addressed. The details should be adequate to provide a clear picture of the how the laboratory will be staffed and operate. The distinction between transition and operations should be explicitly addressed.

NSF would need to establish an oversight body that can address the broadest scope

of underground science thereby placing the NUSL program in a broader context. This body would review the laboratory at least annually and be able to organize more focused reviews to address critical issues or topics.

The project management section of the proposal should identify the important planning documents and processes that are required to define how the project will be managed. Typical documents include project management plans, acquisition plans, quality assurance and safety plans, etc. The proposal should also include a schedule for when these documents will prepared relative to the construction timeline.

Liability issues are raised in the proposal but there is not an adequate discussion of the magnitude of the risks and the manner in which these risks are managed.

The University of Washington is listed as the organization to which the award should be made and the South Dakota Board of Regents is the performing organization. The proposal should therefore address the role of UW and the Board of Regents. The proposal brings these institutions together into CUS therefore there must be point when the grant transfers to CUS.

INSTITUTION: University of Washington
NSF PROGRAM: Particle Astrophysics
PRINCIPAL INVESTIGATOR:
PROPOSAL TITLE: Underground Science for the 21st Century: The National Underground Science Laboratory at Homestake

PANEL SUMMARY:
Criterion 1

The science questions to be pursued in the proposed underground laboratory are among some of the most significant at the intersection of particle and nuclear physics, astrophysics and cosmology. The nature of the facilities which would be provided for experimentation to address these questions will also open opportunities for other areas of science, such as geoscience and microbiology, where such unique laboratory environments are rarely available. Much of this has been outlined in the proposal and in its supporting appendices, and we accept the general conclusions of these documents. It is clear that funding in this area meets a significant need: funding for R&D in underground (UG) science in the US is low, with the result that much of the work in this field is done outside the US. Nor is there a dedicated facility available to serve as a center for UG science in the US.

The proposed laboratory could provide a focus for the field, and help develop an intellectual center for research in the field. The panel agrees that providing experimental access to great depth at the NUSL will be advantageous, and perhaps crucial, for some important experiments. However, the panel found that the present proposal was not sufficiently detailed to allow a determination of whether the laboratory design was optimal or whether all costs for the complete NUSL facility were realistic. In the short time available for development of the proposal, it was not possible to do so. The R&D funding of the UG Program should be used to clarify this issue. In particular, the panel believes that NUSL site should be developed initially in the context of one or a few important experiments.

Criterion 2

This aspect of the proposal was judged by the committee to be outstanding. First, the proposal by its nature is multidisciplinary. It involves in a significant way issues in nuclear physics, particle physics, and astrophysics; opportunities in geoscience, microbiology, and applications of low-level counting techniques also appear likely to be pursued. Therefore, connections to a variety of fields appear certain.

The Underground Laboratory has tremendous potential as a resource for education and outreach. This potential is recognized by the proposers and featured in facilities planned for the Laboratory. These plans should be developed further and optimized--informed

extensively by best practice and the current state of knowledge in science education, pedagogy, evaluation, and outreach--in parallel with the plans for the facility and its research program. The special opportunity to reach and involve Native Americans--a population very underrepresented in science and technology--was recognized and should be pursued.

While we are generally quite impressed with the education and outreach plans, we do have some comments and suggestions. It is generally agreed that the most efficient way to promote science with students of all ages is to expose them to working scientists and their experiments. A bigger effort should be made to make the scientists employed by, or doing experiments at, the laboratory available directly to local students at all levels. Students should also be given the opportunity to become involved with experiments in the laboratory. To accomplish this and other goals, it will be important to establish on-going partnerships with local schools and to devote the resources necessary to support some individual students.

To the extent possible, the activities for visitors should be designed to involve them in an active, not passive, way with the laboratory. Research clearly shows that the visitors will then be much more likely to enjoy and retain their new knowledge.

Finally, there must be a clear plan for assessment and evaluation of the evolving activities in education and outreach.

On the whole, we believe the proposers have done an excellent job of addressing this criterion and that the probability for important contributions in this aspect is high.

Management -

The proposal describes a management model that is very similar to the arrangements used at other national laboratories. The proposal calls for the selection of a laboratory director with a proven record in underground science and project management skills. The selection and appointment of the laboratory director rests with the science board of a not-for-profit consortium, the Consortium for Underground Science (CUS). The consortium represents the interests of the National Science Foundation, the national and international science communities, and the State of South Dakota, its Board of Regents, and its universities. CUS establishes a visiting committee that evaluates the science program, the laboratory director appoints a program advisory committee that advises on the laboratory's scientific program, and a user's committee represents the interests of the scientific community participating the laboratory's research program. The application of the model for laboratory management to the situation at Homestake and the NUSL raise a number of concerns.

The composition of the proposed Consortium for Underground Science (CUS) includes the NSF. It is undesirable and probably even unacceptable for the NSF to be a part of this organization as the NSF has a distinct role as the funding organization. Once the

NSF is removed from the CUS it becomes very similar to Universities Research Associates and Associated Universities Incorporated, the original operating contractors for Fermilab and Brookhaven National Laboratory. These organizations were established to assure that the unique character of academic research is applied to operations of national laboratories. As noted in the proposal the State will secure title to the surface and underground property at Homestake. The Regents and their institutions will participate in the major functions of site operation, site maintenance, and facilities development for science, outreach, and administration.

The review panel concluded that there is not a strong need for a newly formed, tax-exempt, limited liability corporation as proposed. The recipient of a NSF award for the establishment of a National Underground Science Laboratory at Homestake should be the South Dakota Board of Regents. The panel recognizes that the Board of Regents does not possess all of the capabilities required to provide management and oversight of the NUSL and must establish a formal mechanism for augmenting their capabilities with the experience of other institutions, in particular those with experience in managing science facilities that serve diverse user communities. This institutional advisory body to the South Dakota Board of Regents should be designed to play an active role in the formation of the laboratory, in the oversight of laboratory construction, operations, and in the development of the laboratory research program.
The proposal recognizes the importance of the Laboratory Director in the establishment of the NUSL and in the definition of the program of experiments. The panel supports the concept of a Program Advisory Committee that evaluates the NUSL scientific program and reports directly to the Laboratory Director. There is also a need for an advisory body to the NSF and the DOE that addresses the totality of the national program in underground science.

There is very little detail on the organization structure of the laboratory. The roles and responsibilities Laboratory Director and the Associate Laboratory Directors should be addressed. The details should be adequate to provide a clear picture of the how the laboratory will be staffed and operate. The proposal must include specific arrangements that address the requirement of experience in mining construction and operations.

An organization and staffing plan is needed for the next year that maps into the final plan. There are unique circumstances and needs that require an immediate presence at the site and a core of managers, scientists, engineers, and experts working together to develop more detailed plans for the site and the research program.

The project management section of any future proposal should identify the important planning documents and processes that are required to define how the project will be managed. Typical documents include project management plans, acquisition plans, quality assurance and safety plans, etc. The proposal should also include a schedule for when these documents will be prepared relative to the construction timeline.

There is consensus that this proposal addresses questions of enormous scientific

interest. There is also agreement that there is a list of suggested experiments that could attack these problems. We further believe that there is evidence that the Homestake site is both deep enough and large enough to be capable of housing virtually all of the types of proposed experiments. These experiments have yet to be fully fleshed out to the stage where they could be reviewed in any detail. So we find ourselves in a position of having outstanding science goals, a list of potentially important and exciting experiments and a site that will accommodate them. This is an excellent start that we unanimously feel must be pursued. The question we ask is how can a program of this magnitude can be appropriately begun?

Our goal in this consideration is to foster a process that will lead to the development of new ideas and technologies that can be incorporated into proposals for actual experiments that will tackle these fundamental questions. We believe that it is premature to begin the funding of the laboratory without having at least one flagship experiment further along in the design process. Clearly there are some smaller experiments that can benefit from the low background environment of the mine and could be in place relatively quickly. However, for the larger of the proposed experiments more work is needed before even a first round approval can be contemplated.

We later describe a process for the establishment of a coordinated NSF program in Underground Science. This program could begin by funding R&D development activities in a wide variety of areas related to both the science questions and to site development. This would lead to a series of major proposals that could be considered for first use of this new facility. We envision that it might take at least two to three years before the first of these major proposals would be far enough along to be approved. In the interim, resources could be used to develop the infrastructure needed for this new facility and for construction to begin for some of the smaller experiments.

Panel Findings and Recommendations for Underground Science

There are currently major opportunities for addressing exciting scientific questions with an underground facility.

A remarkable suite of underground experiments has revealed, among many other important results, neutrino mass and the fundamental processes by which the sun shines and supernovae explode. These and recent discoveries in dark matter/dark energy and the structure of the Universe, have brought us to a juncture where a new "generation" of experimentation with greater experimental reach is clearly indicated. To be adequately shielded from the cosmic radiation at the surface of the earth, some will require depths not accessible elsewhere. The discovery potential is simply extraordinary, covering physics beyond the Standard Model, fundamental weak interactions, nuclear astrophysics and many more topics that not only fascinates physicists, astronomers and cosmologists, but the public at large. New experiments

may reveal the nature of dark matter and the instability of the proton or observe the next galactic supernova with unmatched instrumentation. An appropriate facilty would also open opportunities for other areas of science, such as geoscience and microbiology.

We recommend the establishment of an NSF program in Underground Science.

The confluence of recent scientific discoveries and detector development, along with the opportunity presented by the availability of Homestake as a potential site for such a facility, make this an opportune time to initiate a national program in underground science. The creation of an NSF program in underground science would provide a focus for intellectual leadership as well as provide for long term support of detector development and construction, laboratory construction and operation plus ongoing support of research and development for underground science. This program would begin by funding R&D development activities in a variety of areas related to both the science questions and to site development. One of the early targets of support would be activities such as workshops and development grants that would lead to a call for major proposals for underground experiments.

The panel believes the scope of underground science warrants the creation of a National Underground Science Laboratory.

The panel believes that, to be scientifically useful, the next generation of underground experiments should strive to achieve at least an order of magnitude improvement in sensitivity with respect to the current experiments. Of necessity, this will require the construction of experiments of a size and complexity beyond those in operation at existing underground laboratories, such as the Gran Sasso laboratory in Italy. The United States has an opportunity to be a world leader in this emerging multi-disciplinary field. We endorse arguments for pooling resources into a single facility that would be the focus of future national and international efforts in underground science. The laboratory would serve as the intellectual center for this science and would provide a focal point for researchers from around the world, much as does Fermilab or CERN.

The Underground laboratory has tremendous potential as a resource for education and outreach.
Plans for these activities should be informed extensively by best practice and the current state of knowledge in science education, pedagogy, evaluation, and outreach- in parallel with the plans for such a facility and its research program.

The Underground Laboratory will serve many fields where research is heavily international.
Underground science, like many other areas of nuclear physics, particle physics, and astrophysics, has long been international in nature. It is crucial that the process which leads the US to the establishment of this laboratory and the resulting plans provide appropriate opportunities for the international scientific community to contribute

substantially, both intellectually and financially, to the success of the project and the research it enables.

A decision to proceed with construction of a National Underground Science Laboratory should be based on a final proposal which explicitly includes cost estimates and plans for surface and underground construction, the first major detectors, outreach, international collaboration, access, and scientific and project management as well as estimate costs for on-going operations and equipment renewal.

The panel agrees that the Homestake site has the potential to be the premier facility for underground science for both US and international scientists.

The proposers have outlined, in their description of the "lower" and "upper" campuses, a facility capable of housing virtually all of the types of experiments envisioned including those which require either greater or equivalent depth than at existing sites. While a full technical evaluation of the underground laboratory spaces which might be constructed has not been done, the knowledge of the geological environment gained from years of mining and the preliminary study of the Technical Evaluation Group (Appendix C) of the proposal provide confidence that the former mining site can evolve into such a premier facility. The physical environment which could be provided for the experiments and the laboratory infrastructure, both above and below ground, at the Homestake site are seen by the panel as capable of offering a synergistic environment for the wide variety of underground science. Attributes of the site at Homestake SD (depth, geology, mine infrastructure) are extremely well suited to this mission. The existing infrastructure has substantial financial value, likely making Homestake a very cost effective site for an underground laboratory.

The panel believes strongly that Homestake must be preserved until a final decision on an underground laboratory are made. It is our understanding that funding has just been secured to support this for at least the next year.

An interim presence should be developed at the Homestake site.

The panel recommends that a scientific presence be established at Homestake to undertake initial activities at the future laboratory and to provide a focus for scientific discussion. Activities would include management oversight of the initial funding for preservation of the mine, and of research and development necessary for further development of the laboratory. Examples might include issues of materials purity and backgrounds.

The construction of the NUSL should proceed in two phases. The first phase of design and construction planning should begin immediately. This phase would include maintaining the safe condition of the Homestake mine, preliminary engineering and

design, construction planning, and general site preparation activities. This work should proceed in parallel with the program for developing the initial set of major experiments and should provide a proper cost and schedule basis for a decision to make a significant investment in the facility infrastructure. These plans should include the infrastructure and additional underground excavation that may be required to accommodate specific experiments.

Education and outreach should be part of activities and planning at the site from the beginning.

PANEL RECOMMENDATION:
PANEL RECOMMENDATION KEY:
DNF:Do Not Fund, FIP:Fund If Possible, F:Fund